Big Qualicum River Salmon Development Project, Volume IV: Chum Fry Marine Study

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Resource Services Branch
Fisheries and Marine Service
Department of Fisheries and Oceans
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Technical Report Number 824

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BIG QUALICUM RIVER SALMON DEVELOPMENT PROJECT
VOLUME IV
CHUM FRY MARINE STUDY

By

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ABSTRACT

Fraser, F. J., S. J. Berry and B. Allen 1979. Big Qualicum River Salmon Development Project, Volume IV. Chum Fry Marine Study. Fish. Mar. Serv., Tech. Rep. Series Number 824, Vancouver, B. C. 32 p.

In conjunction with the Big Qualicum River spawning channel development, a marine study was undertaken during 1969 and 1970 to investigate the migration, feeding habits and sources of mortality for Big Qualicum chum fry.

The results of this study indicate that these fry migrate in a north-westerly direction upon entering Georgia Strait. Evidence suggests that the waters around Denman and Hornby Islands are also utilized for rearing by pink and chum salmon juveniles migrating northwards from the Fraser River.

A bimodal pattern of plankton abundance was recorded for both years, with peaks occurring in mid-June and early September. The downstream migration of the 1969 chum fry coincided closely with a time of maximum plankton levels, while the 1970 chum fry migration peaked approximately one month earlier. Plankton densities varied considerably between years. The salmonid fry examined appeared to be selective about their prey and the chum diet consisted largely of calanoid copepods, euphausiid nauplii and *Oikopleura* sp.. A number of epibenthic organisms were also identified among the stomach contents.

Sources of mortality were not established conclusively. Coho salmon and several species of piscivorous birds are thought to be the main predators.

KEY WORDS: chum salmon fry, migration pattern, feeding, zooplankton, Big Qualicum River.

RÉSUMÉ

Fraser, F. J., S. J. Berry and B. Allen 1979. Big Qualicum River Salmon Development Project, Volume IV. Chum Fry Marine Study. Fish. Mar. Serv., Tech. Rep. Series Number 824, Vancouver, B.C. 32 p.

Parallèlement au développement du canal de frai de la rivière Big Qualicum, on a entrepris, en 1969 et en 1970, une investigation de la migration, des habitudes alimentaires et des causes de la mortalité au sein des populations d'alevins du Saumon keta de cette rivière.

Les résultats démontrent qu'à leur arrivée dans le détroit de Géorgie, les alevins migrent vers le nord-ouest. Nous avons de fortes raisons de penser que les eaux qui entourent les îles Denman et Hornby ont aussi un rôle à jouer dans la croissance des Saumons roses et keta qui migrent vers le nord, à leur sortie du Fraser.

L'abondance du plancton suit une configuration bimodale pendant les deux années de l'étude, et les maxima se situent à la mi-juin et au début de septembre. En 1969, la migration vers la mer des alevins keta a coincidé de très près avec un pic de population de plancton. Par contre, en 1970, cette migration est survenue un mois plus tôt. La densité du plancton varie énormément d'une année à l'autre. Nos observations donnent à penser que les alevins font preuve de certaines préférences dans le choix de leurs proies: les alevins keta se nourrissent surtout de Calanoïdes (Copépodes), de nauplius d'Euphausiacées et d'*Oikopleura*. Les analyses de contenus stomacaux ont aussi permis d'identifier un certain nombre d'organismes benthiques.

Nous n'avons pu établir de façon précise les causes de la mortalité. On croit que le Saumon coho et plusieurs espèces d'oiseaux piscivores sont les principaux prédateurs.

MOTS CLÉS: alevin de Saumon keta, configuration de la migration, nutrition, zooplancton, rivière Big Qualicum.

INTRODUCTION

The Big Qualicum River, a major producer of chum salmon (*Oncorhynchus keta*), is located on the east coast of Vancouver Island (Fig. 1) and releases up to 60 million fry annually (Append. 1). The survival to adult stage averages only 0.7% (Fraser, Lightly, Bailey & Perry, 1979), which is less than one-half the survival rate measured for fish from nearby streams.

In order to properly assess chum salmon survival and to evaluate artificial spawning facilities, fry marking programs have been carried out annually at Big Qualicum since 1965. The release of marked fry provided a unique opportunity to monitor the early life history of juvenile chum salmon in the study area.

A preliminary marine study was conducted during the summer months of 1969 and 1970 with the following objectives:

(1) to define the boundaries of the marine rearing area of Big Qualicum chum fry.
(2) to determine their migration path, feeding habits and identify potential predators.

During 1969 and 1970 fin-clipped fry were released from the Big Qualicum River (Table 1) to determine their distribution within the study area and their contribution as adults to the commercial chum fishery.

The sampling program involved the collection of chum fry from several locations in the study area (Fig. 2) for length-weight measurement and stomach analysis. Plankton samples of potential prey populations were also gathered as researchers have shown that juvenile salmon feed on zooplankton during their early life (Manzer, 1969). Important consequences of diet are suggested by LeBrasseur (1969), who theorizes that the type and quantity of prey available to a young fish may limit its growth rate and therefore its chance of survival against predation (also see Parker, 1971).

Abiotic factors such as temperature, salinity and turbidity were also monitored because they can exert a strong influence on primary and secondary productivity and thus indirectly affect the growth of salmon fry.

DESCRIPTION OF THE STUDY AREA

The study area consisted of the near shore waters of Vancouver Island's east coast, from Cape Lazo to the Little Qualicum River, including the waters around Denman and Hornby Islands (Figs. 1 & 2). Shoreline habitat types on the region range from sand, gravel and rocky shore to mud flats.

Chum salmon, the numerically dominant salmonid species utilizing the area during the period of this marine study, are produced in local streams and rivers listed in Table 2. The Big Qualicum River Salmon Development Project, through the use of artificial spawning channels and flow control, produces the greatest number of these fish.

The other salmonid considered in this study was the pink salmon (*O. gorbuscha*). Due to their unique life cycle, the occurrence of large numbers of pink juveniles within the study area is a biennial event occurring only in 'even' years.

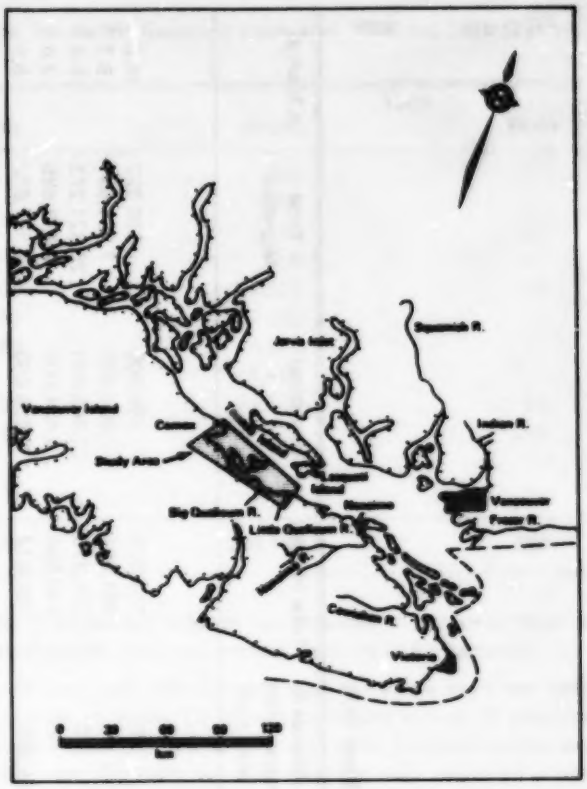


Figure 1. Map of southern British Columbia showing the study area adjacent to the Big Qualicum River.

Figure 2. Detailed map of study area.

Table 1. Number of marked fry released and migration totals from Big Qualicum river, 1969 and 1970.

	Adipose - left ventrals	Adipose - right ventrals	Adipose - anal	Adipose & tetracycline bone mark	Total Marked	Unmarked	Total Migration	% Marked
1969								
To April 30	151,922	0	0	0	151,922	469,000	620,922	24.5
May 1 - 15	664,136	307,845	0	0	951,981	7,004,600	7,956,581	9.7
May 16 - 31	1,246,344	129,929	0	0	1,376,273	23,945,000	25,321,273	5.4
June 1 - 30	188,806	10,789	0	0	199,595	9,634,000	9,833,595	2.0
July	0	0	118,434 (July 2-4)	84,238	202,672	2,205,000	2,397,672	8.5
Below Fence Estimates**						6,100,000	6,100,000	
Grand Total	2,222,000*	446,700*	113,400*	98,340*	2,850,440	49,357,600	51,700,000*	5.5
1970								
To April 30	538,438	281,985	0	0	820,423	13,210,000	14,030,423	6.2
May 1 - 15	477,909	424,599	0	0	902,508	33,786,500	34,689,008	2.7
May 16 - 31	246,158	0	0	0	246,158	2,466,500	2,712,658	10.0
June - July	0	0	77,379 (June 12-23)	0	77,379	1,540,500	1,617,879	5.0
Below Fence Estimates**						10,000,000	10,000,000	
Grand Total	1,259,000*	685,700*	73,150*	0	2,017,850	61,003,500	63,100,000*	3.2

* Corrected for immediate mortality losses from marking.

** Below fence estimates include fry produced by those adults which spawned below the enumeration fence.

Table 2. Estimated adult escapements of chum and pink salmon, by stream, for the Big Qualicum study area, 1968 and 1969 (Zyblut, 1971, 1972).

Stream	1968		1969	
	Chums	Pinks	Chums	Pinks
Cook	6,500	–	900	–
Cougar	1,500	–	350	–
McNaughton	250	–	150	–
Nile	400	–	200	–
Puntledge	55,000	2,100	27,500	100
Big Qualicum	140,000	350	101,000	–
Little Qualicum	85,000	20	75,000	–
Rosewall	6,000	–	1,400	–
Tsable	21,000	250	11,500	50
Tsolum	5,000	5,520	500	200
Waterloo	1,200	–	150	–
Wilfred	2,500	–	1,000	–
Totals	304,350	8,240	219,150	350

METHODS

FISH SAMPLING

Chum fry were sampled biweekly in areas of concentration, during April-September of 1969 and 1970. A three section purse seine 61 m long by 6 m deep was used to capture fry (Fig. 3 & 4a, b). Where practical, fry were also taken with a long handled 0.76 m diameter dip net.

As pink salmon were observed to intermingle with schools of chum fry, incidental catches of pink fry in 1970 were retained in order to compare growth rates, diet and possible interaction between the two species.

Fry were preserved in 10% formalin and measured for length and weight within forty-eight hours. Length-weight data was then analyzed using the equation $W = a L^b$. A coefficient of condition "K" (Rousenfell & Everhart, 1953) was calculated as a means of comparing the physical condition of pink and chum fry sampled in 1970.

$$"K" = \frac{W \times (10^5)}{L^3}$$ (where 'w' is the weight in grams and 'L' is the length in millimeters)

MARKED FRY

The location of chum fry during the 1969 marked recovery program was used to determine index areas for spatial distribution. Those fry captured were examined for fin clips and released. The 1970 recovery program was expanded to include an examination of growth rates and stomach contents of fry captured.

During both years a minimum of one survey every two weeks was made to assess fry density and distribution. If numerous fry were observed in a specific area more frequent surveys were carried out. On calm days fry densities were estimated visually with the aid of polaroid sunglasses.

Fry densities were categorized as follows:

Scattered fry - up to 120 fry/100 m^2
Light density - 120 - 600 fry/100 m^2
Medium density - 600 - 3000 fry/100 m^2
Heavy density - 3000 - 15,000 fry/100 m^2
Very heavy density - over 15,000 fry/100 m^2

To determine the reliability of fry density estimates the field crew periodically estimated the number of fry in a school prior to setting the seine. The total seine catch was then counted and compared to the initial estimate.

PLANKTON SAMPLING

Zooplankton samples were collected once every ten days from April through September 1969 at nine permanent sampling sites distributed along Vancouver Island's eastern coast between Comox Harbour and the mouth of the Little Qualicum River (Fig. 5). During 1970 this pattern was repeated but the station near Bowser was omitted in order to make the program more manageable.

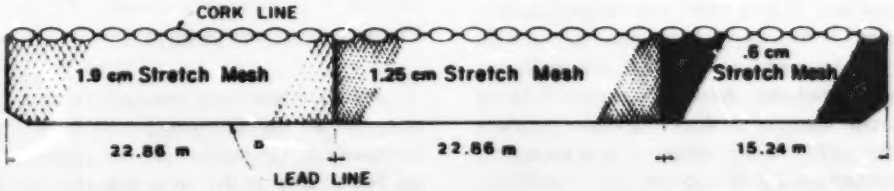


Figure 3. Two man purse seine used in Big Qualicum Study area, 1969 - 1970.

Figure 4a. A demonstration of pursing the two-man seine net.

Figure 4b. Medium sized catch of chum and pink salmon.

Figure 5. Plankton sampling stations in the study area, 1969-1970.

Two sampling locations were chosen at each site: an inshore station and an offshore station. In 1969 vertical hauls not exceeding 6.0 m in depth were taken at inshore stations located permanently regardless of tidal conditions. Duplicate hauls were made at each depth sampled. During 1970, the inshore stations were relocated according to the stage of the tide, to maintain a constant surface to bottom sampling depth of 3.0 m. Observations made in 1969 suggested that chum fry are seldom found below this depth before moving offshore. Offshore stations were established further offshore at depths of approximately 27 m. Sampling consisted of two 3.0 m and two 12.0 m plankton hauls at each site.

A 'Wisconsin' sampler with a 25.4 cm aperature and a collecting cup mesh size of 452 microns was used during 1969 plankton hauls (Fig. 6a). This sampler was lost in 1970 and replaced by a conical net 25.4 cm wide at the mouth. The collecting bucket had the same mesh size as the original sampler (Fig. 6b).

PLANKTON COUNTING

To obtain plankton counts each of the 1969 samples were standardized to a 50 ml volume. Three 1-ml replicates were obtained by subsampling and then counted in Sedgwich-Rafter cells. The 1970 plankton samples were diluted up to a 6 liter volume, depending upon their density, stirred vigorously and subsampled three times with a 250 ml measuring beaker. Plankton counts were made in a gridded 50 mm petri dish.

STOMACH ANALYSIS

Fish stomachs were removed in the laboratory and an estimate of their fullness made. Stomach contents were then examined under a stereoscopic dissecting microscope and identified to the lowest practical taxonomic category.

The examination of a large number of stomachs in 1970 (over 1100) made the more laborious volumetric and gravimetric methods of measuring stomach contents impractical. As an alternative the number of prey present were counted and their percent occurrence calculated. (The percent occurrence gives the proportion of all fish stomachs in which a given food organism occurs.)

PHYSICAL PARAMETERS

Water temperature and salinity data for the study area was collected at the Chrome Island light house (Fig. 2). Water transparency (or turbidity) was measured using a standard 20 cm Secchi disc at the same time that plankton hauls were completed.

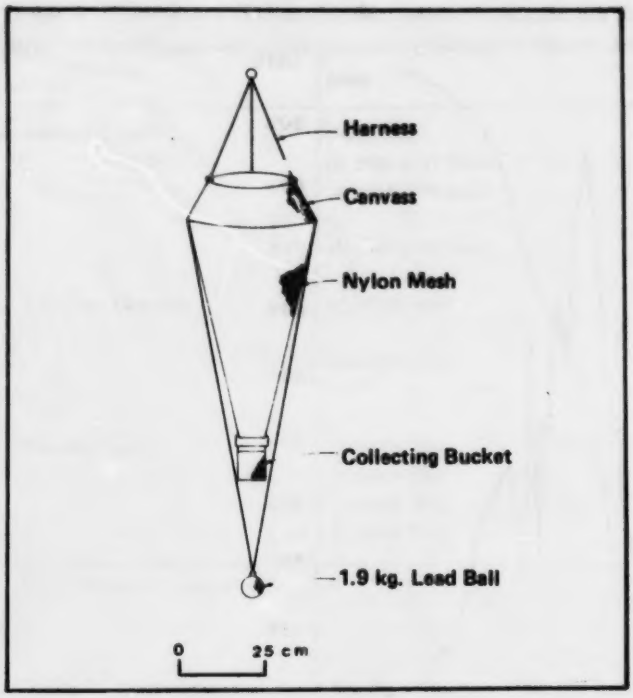


Figure 6a. "Wisconsin" plankton sampler used in 1969.

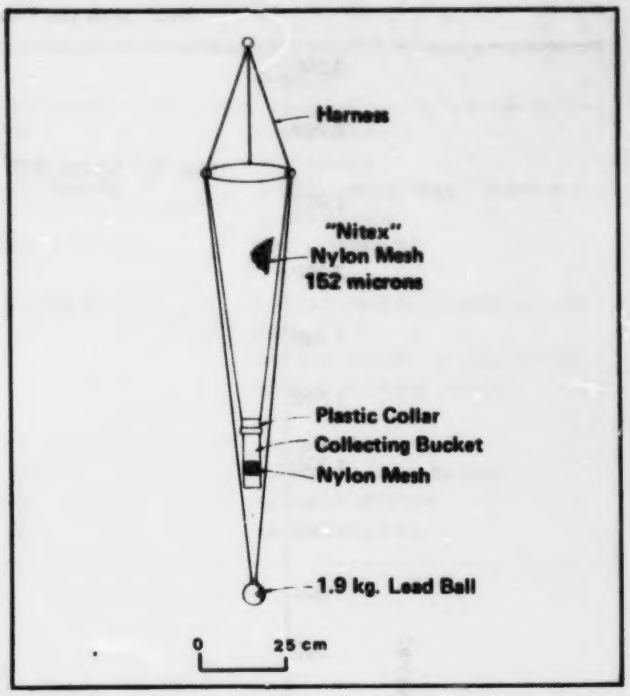


Figure 6b. "Conical" plankton sampler used in 1970.

RESULTS

CHUM FRY DENSITY AND DISTRIBUTION

The majority of chum salmon fry within the study area migrate to the sea between April and June (Fig. 7) (Fraser, Lightly, Bailey and Perry, 1979). The Big Qualicum River in 1969 and 1970 contributed between 60 and 75 percent of the total estimated chum fry production for the mid-Vancouver Island region (Table 1 and Appendix II). Therefore a large proportion of chum fry encountered in the study area were expected to be of Big Qualicum origin.

During 1969, 53 million chum fry migrated downstream between May 1 and June 15 with peak migration occurring near the end of May (Fig. 7). Table 3 records the gradual northerly migration of fry.

A periodic survey (May - August 1969) of the shoreline south of the Big Qualicum River was made to determine if some chum fry migrate south. The survey extended one mile past the Little Qualicum River where only a few fry were observed. This observation supports the hypothesis that the majority of chum fry migrate in a north-westerly direction. It is believed that some fry follow the shoreline while others are thought to parallel the shore in deeper water.

Sixty-three million Big Qualicum chum migrated downstream in 1970 between April 10th and May 20th (Fig. 7). Peak migration occurred at the beginning of May, one month earlier than in the previous year. Table 4 records their movements for 1970.

Young chum salmon were most frequently found near rocky shores, amidst weed or kelp beds and in areas under or adjacent to wharves and docks. Very few salmonid fry were noted in open, sandy areas such as the head of Tribune Bay.

Visual observations made during 1969 and 1970 suggest that smaller chum fry prefer waters for which the depth does not exceed three meters. The preferred depth appears to increase with size and age of the fish. Fry larger than 75 mm showed little affinity for weed cover and chose areas of deeper water and/or greater tidal movement. In Lambert Channel large chum and pink fry (90+ mm in size) were observed to feed actively in tidal currents up to 5 knots per hour.

During 1970, pink salmon fry were captured incidental to the chum fry investigation. Large numbers of pinks were located at the northwestern end of Lasqueti Island in early June. The percentage of pink fry present there in the individual seine catches was as much as 71% of 7,000 salmonids. They were most numerous relative to other species at St. John Point and Tribune Bay where they accounted for 18% of the salmonid catch when compared to 9% in the remainder of the study area.

MARKED FRY

To determine what proportion of the total chum fry population in the study area originated from the Big Qualicum river the seine recovery rate of marked fish was examined. Out of approximately 2,850,000 fin-clipped fry released from Big Qualicum in 1969 only 16 marked fry (.06% of those checked) were recovered (Figure 8).

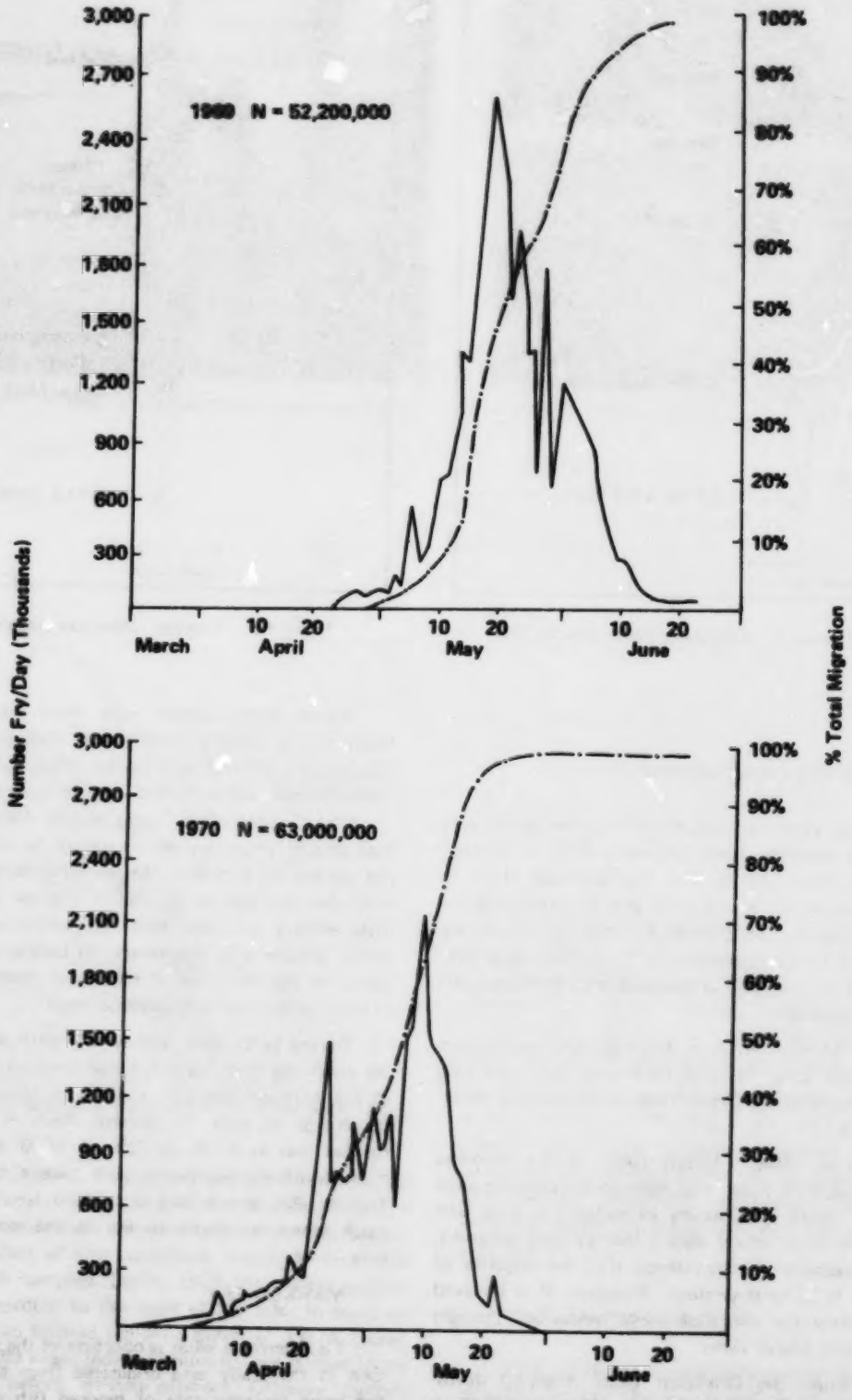


Figure 7. Chum fry downstream migration at Big Qualicum River, 1969 and 1970. 'N' shows total number of migrants. (Unpublished data from Big Qualicum River Development Project).

Table 3. Observations of chum fry distribution within the Big Qualicum Study Area, 1969.

	Area	Date	Density[a]
Baynes Sound	Deep Bay	April 14	scattered fry
	all sheltered bays	May 15	light density
	all sheltered bays	June 15 - July 15	decrease along shore; movement to deeper water
	all sheltered bays	July 23	very scattered fry
Lambert Channel	southern end	May 1 - July 17	medium density; peaking in mid-June
	northern end	July	fry first present in July, all fish offshore in deeper waters
Hornby Island	Tribune Bay	May 11	scattered fry
	Tribune Bay	June 14	medium to heavy density
	Tribune Bay	June 25	migration offshore
	Tribune Bay	July 25	very scattered fry

[a] See methods for density definitions.

Table 4. Observations of chum fry distribution within the Big Qualicum Study Area, 1970.

	Area	Date	Density
Baynes Sound	Deep Bay	April 8	scattered fry
	Deep Bay	May 15 - 19	medium density
	Deep Bay	June 29	very scattered fry: coincident with arrival of coho smolts
Baynes Sound	Mud Bay	May	scattered
	Mud Bay	June 15	peak density
	Fanny Bay	May 5	scattered
	Fanny Bay	May 25	peak numbers (medium)
	Fanny Bay	June 19	all fry gone
	Buckley Bay	same as Fanny Bay with higher densities (medium to heavy at peak)	
	Union Bay	April 15	first fry recorded
	Union Bay	June	moderately heavy density
	Union Bay	June 13 - 23	fry migrating offshore
	Cape Lazo	June 22	very scattered
	Cape Lazo	July 1	highest density
	Cape Lazo	July 25	all salmonids gone
Lambert Channel	southern end	April 21	first fry sighted
	southern end	June 5	'medium' to very heavy'
	southern end	June 19	decreased to scattered fry indicating possible northward movement
Hornby Island	Northern Lambert	July 22	'heavy' density
	Tribune Bay	May 6	very heavy
	Tribune Bay	June 25	scattered
	Flora Island	June 25	'medium' density
	Flora Island	July 22	—
	Flora Island	August	no chum fry present

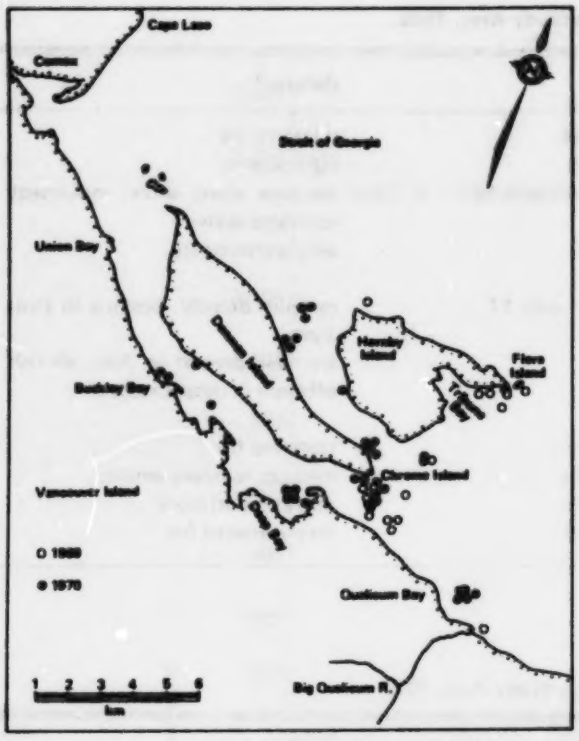


Figure 8. Marked chum fry recoveries for 1969 and 1970.

The 1970 recovery efforts were more successful with 2,017,-850 fin-clipped chum released in April (Table 4) and 34 marked fry being recaptured (0.71% of the 4,700 fry checked for marks) (Fig. 8).

The ratio of marked-to-unmarked fry leaving the Big Qualicum River in 1969 was 1:18 versus 1:1400 recaptured. In 1970 the ratio of fry leaving was 1:30 while the seasonal recapture rate of marked fry was 1:140.

Before marked-to-unmarked ratio could be converted to a percentage an adjustment was necessary because ot the higher initial mortality rate which fin-clipped fry experience over unmarked fry (Parker et al 1961, Fry 1961). Apparent mark-related mortality in fin-clipped 1968 and 1969 brood fish returning as adults was 5% (Fraser et al. 1979). By adjusting the marked-to-unmarked ratio of chum fry in the study area by 5%, a gross estimate of the 1970 seasonal mean percentage of Big Qualicum chum fry in the study area was set at 22.4%, a figure substantially less than the expected 60 to 75%.

FRY GROWTH

The pooled length-weight data for both 1969 and 1970 juvenile chum and pink fry are presented in Figure 9. A comparison of the slope "b" ($W = aL^b$) for both years indicates similar growth rates for both years. Examination of length alone reveals that the 1970 fish sampled were all well under 100 mm while many 1969 fry exceeded 100 mm in length.

From mid-April 1970 until the end of June, the mean weight gain was 3% per day while a daily mean gain of 2.1% was recorded during July and August (Table 5). According to a U test (Freund, 1971) no statistical differences were noted between the size of chum and pink salmon fry captured in the Big Qualicum area (Fig. 10).

Condition coefficient ("K") values calculated for the 1970 chum and pinks ranged from 0.84 to 1.12 (Table 5), indicating an uneven growth pattern whereby length and weight varied with time in proportion to one another.

SEASONAL PLANKTON ABUNDANCE

Plankton densities for inshore stations sampled in 1969 and 1970 were computed and averaged for each sampling date to give the total mean plankton abundance for the study area over time (Fig. 11). The seasonal population density for zooplankton from the Big Qualicum area in 1969 was bimodal with an initial peak observed in mid-June and another in September (Fig.11).

During mid June of 1969, inshore mean plankton densities reached as high as 32,000 zooplankton/m^3 while the September 1969 totals peaked around 22,000 zooplankton/m^3 (Fig. 11). Minimum plankton levels between 7,000-12,000 zooplankton/m^3 were recorded in April and July.

Plankton densities at offshore stations for 1969 followed the same seasonal pattern but with few exceptions, were lower than densities measured at inshore stations. As most plankters migrate to deeper waters during the daytime (Hardy, 1970), the offshore vertical hauls may not have been made deep enough to capture a representative sample of the population and therefore underestimated offshore plankton densities. Offshore data for 1969 and 1970 were therefore not used in the analysis.

The 1970 inshore mean plankton pattern was similar to that of 1969 (Fig. 11). However, overall seasonal averages for 1970 were as much as 30% lower than those calculated for the same period of 1969. Mean densities in 1970 ranged between 4,000 and 16,000 zooplankton/m^3 with peaks of 17,500 zooplankton/m^3 and 22,000 zooplankton/m^3 occurring in June and September respectively (Fig. 11).

Plankton abundance varied between sampling sites (Table 6), but the difference was not significant ($p > .05$). The maximum seasonal variation in plankton density occurred at Buckley Bay where on April 22, 1969 a density of 12,000 zooplankton/m^3 was observed, compared to 65,000 zooplankton/m^3 measured nine days later - a fourfold increase.

To obtain a profile of the major plankton species present in the study area, the seasonal mean density of individual species was calculated using the values from inshore stations (Table 7). A comparison of plankton composition in 1969 and 1970 revealed a change in the dominant species as indicated by the high proportion of copepod nauplii in 1969 (25%), contrasted with their decrease to 5.4% of plankton total in 1970. Cirripede (barnacle) nauplii, somewhat transient members of the plankton community were much more prolific in 1970 (29% of the total plankton in 1970 compared to only 4% in 1969).

The seasonal abundance of *Calanus plumchrus* and the larval tunicate *Oikopleura sp.* was examined carefully because these

Table 5. Mean lengths, weights, condition coefficient (K) and percent increase in weight per day in pink and chum salmon fry, Big Qualicum study area, April to August 1970.

Chums	Fish Sample Size	Mean Length (mm)	Mean Weight (g)	Weight Increase (% per day)	K
April 13 - 30	186	37.0	0.40		0.79
May 1 - 15	537	38.6	0.47	1.0	0.82
May 16 - 31	531	49.4	1.40	4.4	1.16
June 1 - 15	139	69.4	3.73	4.2	1.11
June 16 - 30	268	75.7	4.98	1.7	1.14
July 1 - 15	105	101.3	11.07	3.7	1.08
July 16 - 31	181	107.2	13.00	1.0	1.05
August 1 - 15	19	116.9	17.50	1.7	1.09
August 16 - 31	21	132.1	26.90	2.2	1.12
Total	1,987				

Pinks	Fish Sample Size	Mean Length (mm)	Mean Weight (g)	Weight Increase (% per day)	K
April 13 - 30	1	40.0	0.41		0.64
May 1 - 15	5	38.3	0.45	0.5	0.80
May 16 - 31	60	57.2	1.81	4.7	0.97
June 1 - 15	76	72.6	3.52	3.2	0.92
June 16 - 30	31	78.2	4.78	1.8	1.00
July 1 - 15	1	95.0	8.71	3.0	1.01
July 16 - 30	34	109.3	13.06	2.2	1.00
August 1 - 15	3	128.0	21.69	2.7	1.03
Total	211				

Table 6. Mean plankton densities/m^3 ($x10^3$) for individual inshore stations in the Big Qualicum Study Area, 1969 and 1970.

Station	1969		1970	
	May - June	July - August	May - June	July - August
Buckley Bay	32.8	16.9	15.3	19.6
Fanny Bay	24.1	12.4	11.7	9.8
Mud Bay	24.0	9.7	12.6	5.7
Chrome Island	21.7	14.7	10.1	9.5
Deep Bay	19.5	12.3	15.0	15.8
Comox Harbour	19.2	21.6	9.1	15.4
Tribune Bay	18.1	10.8	10.1	13.5
Little Qualicum River	16.1	16.7	11.1	10.0
Bowser	16.4	16.7	–	–

Table 7. Mean seasonal densities of dominant plankton species at inshore stations.

1969	No. /m^3	1970	No. /m^3
Copepod nauplii	*4,065	Barnacle nauplii	*3,518
Calanoid copepodite	3,839	Oithona	*2,790
Oithona	1,523	Calanoid copepodite	*1,826
Oikopleura	*1,429	Oikopleura	*1,245
Pelecypoda	1,365	Evadne	*1,235
Calanus plumchrus	*1,311	Copepod nauplii	* 659
Rotifera	795	Pseudocalanus	433
Barnacle nauplii	* 772	Paracalanus	235
Acartia	336	Polychaeta	223
Polychaeta	294	Podon	98
Evadne	* 263		
Cyphona Larva	167		
Cyclopoid copepodite	154		
Philidium	134		
Unidentified	105		
Total	16,552	Total	12,262

* Denotes organisms found in the chum stomachs.

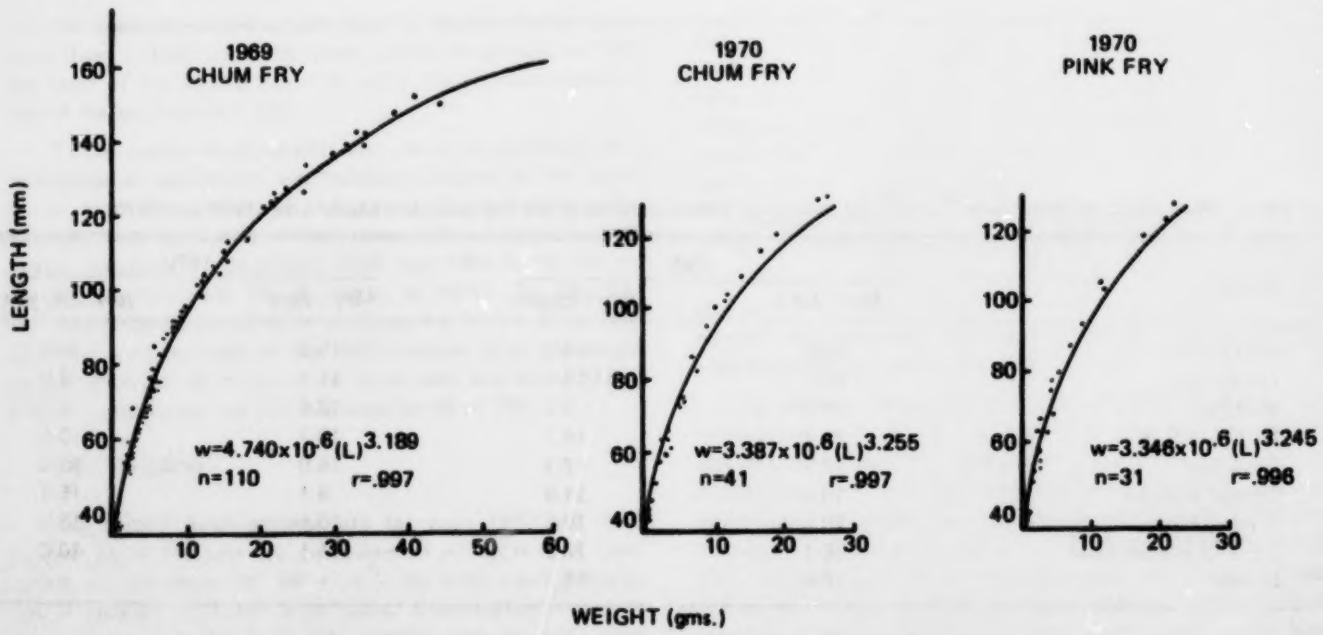


Figure 9. Length-weight relationships for pink and chum salmon fry, Big Qualicum study area, 1969 and 1970.

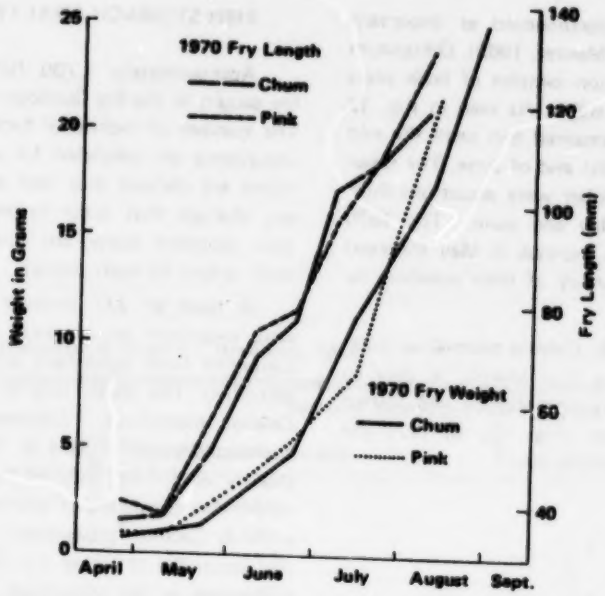


Figure 10. Increase in mean length and weight of chum fry and pink fry from Big Qualicum study area, 1970. (See table 6 for sample size).

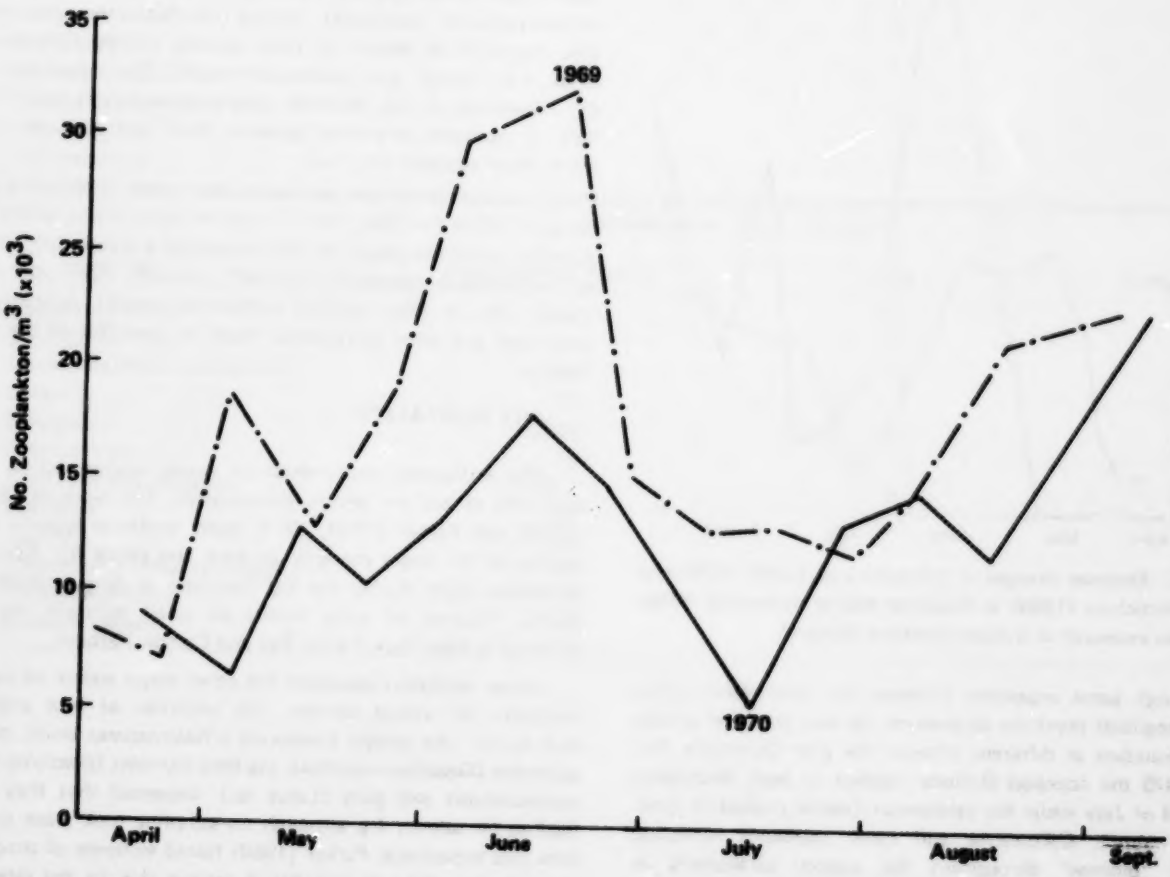


Figure 11. Seasonal mean plankton abundance for inshore stations during 1969 and 1970. (Mean values calculated from nine inshore stations.)

two species have been previously documented as important food items for juvenile chum salmon (Manzer, 1969). *Oikopleura* were commonly present in the plankton samples of both years and their abundance remained fairly stable. As seen in Fig. 12, the *Oikopleura* densities for 1969 remained low until the end of May and reached their peak near the end of June. The mean numbers present from July to September were about one-third lower than those found between May and June. The 1970 *Oikopleura* densities showed a sharp increase in May followed by a sudden drop in July and a recovery of their numbers by August.

Between April and June of 1969, *Calanus plumchrus* numbers were less than 1,000/m^3. They rose sharply in July to 3,000 *C. plumchrus* per m^3, then dropped slightly and leveled off until the beginning of September (Fig. 12). In 1970 the estimated density of *C. plumchrus* was only 8/m^3.

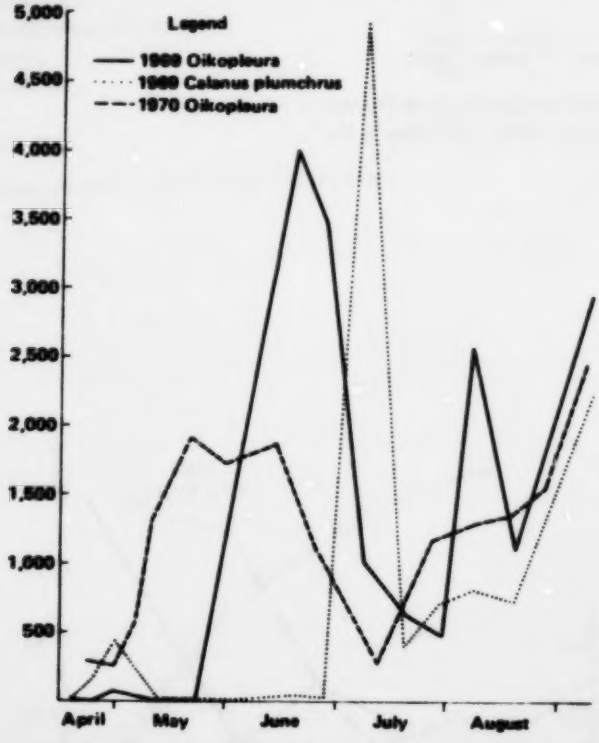


Figure 12. Seasonal changes of *Oikopleura* sp. (1969, 1970) and *Calanus plumchrus* (1969) in Qualicum marine study area. (Mean daily values measured at inshore plankton stations).

Although some organisms followed the twin-peaked curve of mean seasonal plankton abundance, various plankton groups became abundant at different times of the year (Appendix IV). During 1970 the copepod *Oithona* reached its peak abundance at the end of July while the caldoceran *Evadne* peaked in June. Barnacle nauplii, *Oikopleura* and other copepods exhibited successive "blooms" throughout the season, particularly in June and September. *Calanus plumchrus* were most abundant in April and then appeared less frequently among the plankton samples.

FISH STOMACH ANALYSIS

Approximately 1,700 fish stomachs were analyzed from fry caught in the Big Qualicum study area during 1969 and 1970. The number of individual food items counted and their percent occurrence are tabulated for each year in Tables 8 to 10. The tables are divided into two sections as a means of comparing any changes that occur in the diet over time. On the basis of their numbers alone, the five most dominant food organisms were ranked for each station.

A total of 277 juvenile chum salmon captured in 1969 were examined for stomach contents. All stomachs examined contained food. Seventeen different types of zooplankton were identified. The chum diet in 1969 consisted mainly (80%) of *Calanus plumchrus, Calanus pacificus, Oikopleura* sp. and euphausiid nauplii (Table 8). Their diet appeared to change only slightly with time. Smaller fry (< 50mm) maintained a more varied diet consisting of smaller zooplankters while big organisms such as *Calanus plumchrus* were most frequently observed in the stomachs of larger fry (50+mm) (Append. X). After July a decrease in the occurrence of *C. plumchrus* was noted in fish of all sizes.

Table 9 displays the results for the 1,100 chum fry stomachs sampled in 1970. Those stomachs examined contained 20 different planktonic species including a few epibenthic forms (ie. harpacticoid copepods). During July-September the chum diet consisted of about 13 prey species, mainly *Oikopleura*, larval crab forms, and euphausiid nauplii. The occurrence of *C. plumchrus* in fry stomachs also decreased with time from 17% in stomachs examined between April and June, to only 6% of those sampled after July.

Examination of the stomachs from pink salmon fry collected in 1970 (~ 250) showed that the pinks fed on similar organisms as did the chum fry but contained a greater percentage of harpacticoid copepods, especially between April and June (Table 10). In later samples euphausiid nauplii, polychaetes, crab zoea and some *Oikopleura* made up over 75% of the pink fry diet.

FRY MORTALITY

The ecological relationships of young salmon during their early life at sea are poorly documented. The work of Hunter (1959) and Parker (1968, 1971) both implicate juvenile coho salmon as the major predator of pink and chum fry. Field observations made during the Big Qualicum study supported this theory. Feeding by coho smolts on small salmonid fry was observed at Deep Bay, Fanny Bay and Comox Harbour.

Avian predators represent the other major source of natural mortality for young salmon. The activities of four principal bird types: the pelagic cormorant (*Phalacrocorax urile*), pigeon guillemot (*Cepphus columbia*), marbled murrelet (*Brachyramphus marmoratum*) and gulls (*Larus* sp.) suggested that they were feeding on salmon fry, although no sampling took place to confirm this hypothesis. Parker (1968) found evidence of predation by gulls but did not consider it serious due to the relatively small number of gulls within his study area. Ten other piscivorous bird species (listed in Append. V) were frequently ob-

Table 8. Incidence of planktonic organisms in chum fry stomachs, 1968.

N = 186	Samples taken June 14 - June 26		
Organism	Total Number Present	Rank	% Occurrence
Oikopleura sp.	55,580	1	94
Calanus plumchrus	3,924	2	87
Evadne	221		18
Copepod nauplii	473	4	16
Insecta	33		12
Others	340	5	11
Euphausiid nauplii	283		5
Centrophages	48		5
Podon	585	3	3
Fish Larva	7		3
Barnacle nauplii	21		3
Calanus plumchrus nauplii	19		2
Gastropod	5		2.
Parathermisto	5		2

N - 91	Samples taken July 1 - August 1		
Organism	Total Number Present	Rank	% Occurrence
Euphausiid nauplii	5,011	2	84
Calanus pacificus	1,906	3	81
Calanus pacificus copepodites	6,498	1	78
Others	23		37
Oikopleura	1,736	4	19
Parathermisto	19		12
Crab zoea and megalops	617	5	70
Fish larva	10		7
Insecta	71		6
Calanus plumchrus copepodite	13		2
Calanus plumchrus	2		2
Barnacle nauplii	8		2

Table 9. Incidence of planktonic organisms in chum fry stomachs, 1970.

N = 910	Samples taken April - June		
Organism	Total Number Present	Rank	% Occurrence
Harpacticoid copepod	7,523	3	48
Euphausiid nauplii	15,000	2	39
Oikopleura	39,366	1	35
Polychaeta	3,784	5	26
Barnacle cypris	1,315		22
Evadne	6,111	4	20
Insecta	404		18
Calanus plumchrus	1,405		17
Amphipods	621		13
Mysids	2,181		13
Calanoid copepodite	824		13
Decapod larva	583		9
Podon	3,009		7
Barnacle nauplii	317		7
Copepod nauplii	400		4
Pseudocalanus	72		4
Calanus pacificus	219		4
Centrophages	149		3
Crab zoea	70		3
Sagitta	438		2

N = 221	Samples taken July - September		
Organism	Total Number Present	Rank	% Occurrence
Oikopleura	4,807	1	32
Euphausiid nauplii	143	5	25
Crab zoea	537	2	14
Harpacticoid copepod	211	4	10
Amphipods	82		8
Calanus plumchrus	40		6
Fish larva	132		6
Polychaeta	41		6
Calanoid copepodite	45		5
Mysids	45		5
Crab megalops	218	3	3
Insecta	20		3
Pseudocalanus	8		3

Table 10. Incidence of planktonic organisms in pink fry stomachs, 1970.

N = 217	Samples taken April - June		
Organism	Total Number Present	Rank	% Occurrence
Harpacticoid copepods	5,505	1	69
Oikopleura	4,372	2	46
Euphausiid nauplii	2,513	3	37
Barnacle cypris	316		21
Amphipods	385		19
Mysids	372		16
Calanus plumchrus	485	5	14
Evadne	748	4	13
Copepod nauplii	382		13
Calanoid copepodite	120		13
Insecta	25		9
Polychaeta	17		7
Pseudocalanus	28		7
Oithona	16		5
Tortanus	15		5
Podon	97		4
Sagitta	237		2

N = 29	Samples taken July - September		
Organism	Total Number Present	Rank	% Occurrence
Euphausiid nauplii	117	3	38
Polychaeta	42	4	34
Crab zoea	227	2	31
Oikopleura	325	1	21
Fish larva	17	5	14
Harpacticoid copepods	9		14
Calanus plumchrus	8		10

served in close association with schools of pink and chum fry. Loons, grebes, herons and mergansers were observed feeding in areas where chum fry were known to be during the early part of their marine residence.

PHYSICAL PARAMETERS

Data from the Chrome Island station indicate that the surface water temperatures (0.9 m depth) were similar for 1969 and 1970, increasing from 7°C in April to 20° in July and August (Fig. 13a).

Salinity readings fluctuated considerably more in 1969 than in 1970 (Fig. 13b). During April, May and August of 1969 salinity remained steady between 26 and 29‰. During June and July salinity dropped to around 23‰, with a low of 16 parts per thousand recorded in mid-June. Throughout 1970, salinity values remained steady between 27-29‰.

Water transparency (turbidity) data as measured with a secchi disc at the plankton sampling stations is presented in Appendix VI & VII. Secchi disc readings for 1969 and 1970 are similar in their range of values and absence of a seasonal pattern.

DISCUSSION

FRY DISTRIBUTION

While the sightings of chum fry made in both 1969 and 1970 were restricted to a period of five months (mid-April until September), the data indicates that Baynes Sound, Lambert Channel and Tribune Bay (on Hornby Island), all receive significant numbers of fry during this time of the year.

After leaving their natal streams, most chum fry were found in inter-tidal areas at depths up to five meters. The preferred habitats were areas which provided a measure of cover, and therefore possible protection against predators. Goodman and Vroom (1974) as well as Healey et al. (1976), have observed that fry and smolts spend considerable time in shallow near-shore habitats after leaving freshwater. Chum fry migrating down the Fraser River also display this behaviour, termed "estuarine holding" by Dunford (1975).

Big Qualicum chum fry remained inshore during both years until the second or third week in June when they migrated offshore to deeper waters. After the third week in July only

Figure 13a. Seasonal profile of temperature (0.9m) measured at Chrome Island, 1969, 1970.

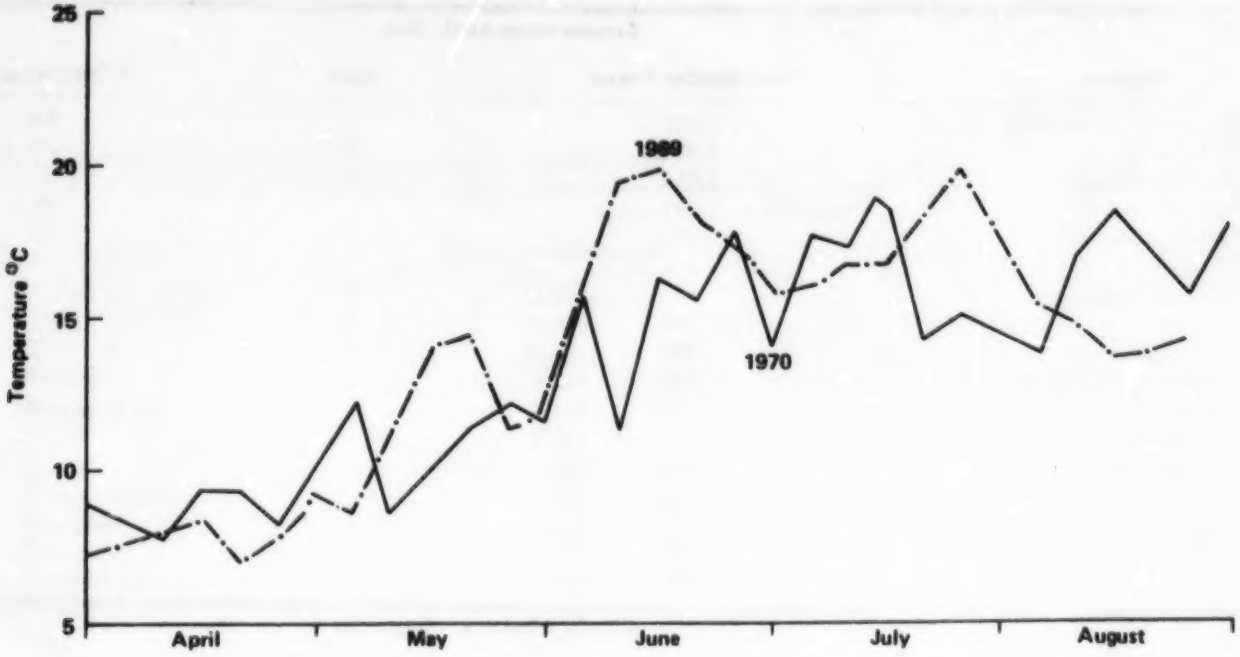
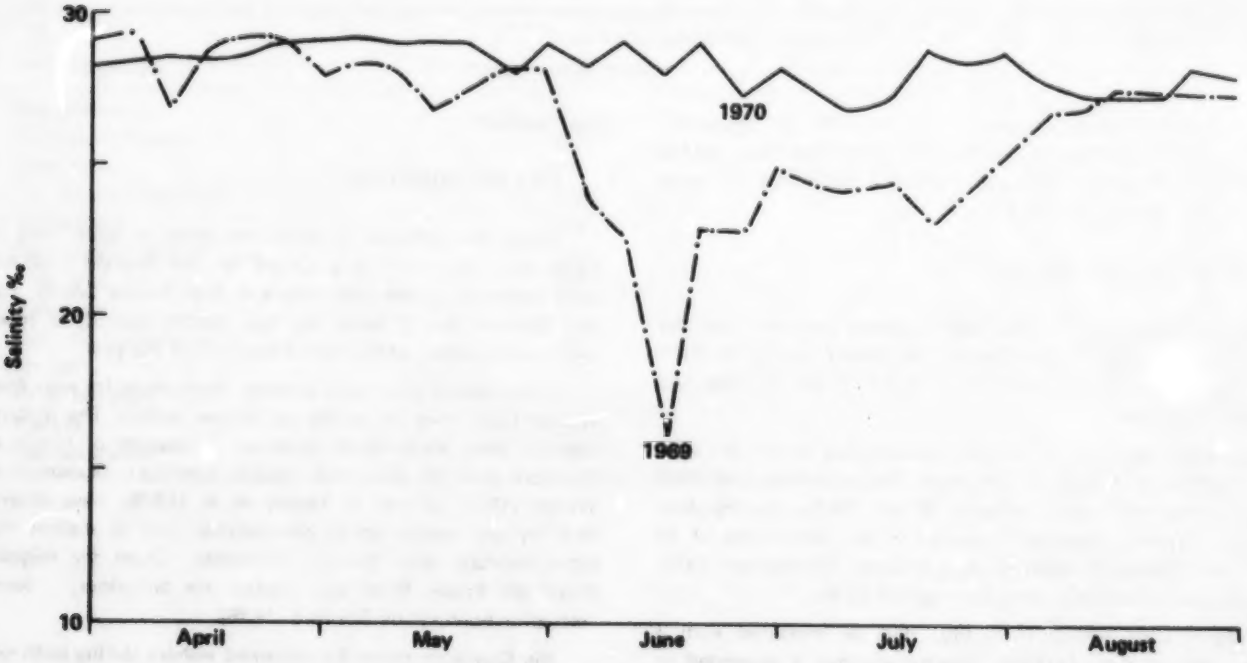


Figure 13b. Seasonal profile of salinity (0.9m) measured at Chrome Island light house, 1969, 1970.



small numbers of chum fry were present offshore and by the end of August virtually all fry were gone. The results of this study suggest that the fry remain in adjacent waters between one and four weeks prior to their departure from the study area.

MARKED FRY

Recovery of fin-marked chum fry indicated a general northwest migrational pattern in 1969 and 1970. This observation was supported by the absence of fry observed moving along the shoreline south-east of the Little Qualicum River and by the small number of fry caught in sets where the seine was placed open to the north. It is believed that some fry follow the coast while others move more directly offshore. The results of other tagging experiments (Hart et al. 1969) strongly suggest that all species of juvenile salmon move northward along the coast of B.C. during their first summer.

Analysis of the recoveries of marked fry yielded an estimate that 22% of all chum fry in the study area in 1970 originated from the Big Qualicum River. Due to varying intensity in the search for marked fry, this value may underestimate the true number of marked fry present.

It is very probable that fry from other streams move into and through the study area during the summer months. Strong indications exist that the waters around Denman and Hornby Islands receive a large influx of lower mainland salmonid fry. An estimated 134 million chum fry were produced by the Fraser River in 1970 and many of these fish are believed to have migrated northward. This may explain why such a small fraction (only 22%) of the chum fry observed in the area were of Big Qualicum origin. Table 11 lists the total number of chum fry produced from major tributary rivers of Georgia Strait. When all major streams are considered one can see that the contribution of Big Qualicum to Georgia Straits is only 22%.

Table 11. 1976 Chum salmon fry production estimate for southern B.C. (Major streams in Georgia Strait)[a]

Area	Fry Production (No. x 10^6)
Big Qualicum river	63.0
Little Qualicum river	16.9
Toba inlet	4.3
Jervis inlet	21.8
Lower Vancouver Is.	10.8
Southern Vancouver Is.	21.4
Howe Sound	10.8
Burrard Inlet	3.4
Fraser river	135.4
Total	**287.8**

$$1970\ BQR = \frac{63.0}{287.3} = 21.89\% = 22\%$$

[a] (Calculated from 1969 adult escapements where the number of females estimated to be 0.5 with 3000 eggs/female and 15% egg-to-fry survival).

In 1970 large numbers of pink fry were found schooling quite closely with chum fry in the study area. These fish probably originated in the Fraser River, as no major pink salmon-producing streams south of Comox exist on Vancouver Island. A northwest migration in 1970 of numerous pink fry (20%) from Fraser river to Texada and Lasqueti Islands was reported by the International Pacific Salmon Fisheries Commission (A. Chapman, pers. comm. and I.P.S.F.C. Annual Report for 1970, p. 24). Movement from the north end of Lasqueti Island to Flora Island and Baynes Sound is a natural extension of the previously described migration. Since pink and chum fry from the Fraser River were found in close association at Lasqueti Island, it seems reasonable that both species migrated across Georgia Strait to the Baynes Sound-Qualicum area.

FRY GROWTH

The growth rates of chum salmon fry were similar for the two years. The slope of the 1969 and 1970 length-weight relationships was comparable to those values reported by Vanstone (1966) for two groups of Big Qualicum chum fry reared in seapens. Between April 13 and May 15, 1970, the increase in weight of chum fry was estimated to be only 1% per day which is substantially lower than the 6.2% daily weight gain recorded by Vanstone et al. (loc. cit.). This difference may be attributed to the recruitment of small chum fry into the study area in early May of 1970 when the downstream migration of Big Qualicum chum fry had peaked. These fry would negatively bias the true growth rate. Similarly, in 1970, a 2 mm decrease noted in the mean length of pink fry during the first half of May could also be the result of smaller fry migrating into the study area. Furthermore, it is suspected that large fry (>75 mm) are better able to avoid capture by dip-nets than smaller fry. Since dip nets were frequently utilized during the first part of the season, early April chum fry samples may be further weighted towards the smaller fry.

ZOOPLANKTON ABUNDANCE

Zooplankton densities are difficult to estimate because of their uneven and changing distribution in the water column (Parsons and Takahashi, 1973). For our purposes, mean plankton values serve as a general index of plankton abundance for each of the years studied. To obtain a more accurate cross section of the plankton species present, horizontal as well as vertical plankton tows should be used when sampling.

The time of day at which a sample is taken may also affect the results since plankton migrate diurnally. Calanoid copepods for example, are most abundant near the surface at dusk or sunset and disappear to deeper waters at noon when the sun is most intense (Hardy, 1970). As this factor was not considered when sampling for this study, estimates made of plankton abundance may be affected.

Similar patterns of seasonal zooplankton abundance were exhibited in 1969 and 1970. An oscillating pattern resulted as different zooplankton groups became abundant at different times throughout the summer. The two peaks which occurred

in mid-June and early September probably reflected the seasonal reproductive cycle of the more abundant copepods and invertebrates (Heinrich, 1962).

The composition of plankton samples varied seasonally as well as between years. The most noticeable change in species was for *Calanus plumchrus* whose numbers dropped considerably during July of both years. An explanation of this is made by Fulton (1973) who states that *C. plumchrus* migrate to the surface waters in spring to utilize the high phytoplankton productivity there, but descend to deeper waters during the summer. Consequently shallow inshore sampling after July may have missed a large percentage of the *C. plumchrus* population.

The total plankton values measured for 1970 were about 25% lower than those of the previous year. This variation was not shown to be directly related to those physical parameters measured. Buckley Bay recorded the greatest seasonal variation in zooplankton abundance. Parsons and LeBrasseur (1968) have attributed such extreme variation to wind movement but it is also probable that tide or eddies act to concentrate surface plankton (Ruttner, 1972).

Extreme fluctuations in annual plankton abundance could negatively affect the growth and possible survival of juvenile salmon in years of low plankton and high fry densities. Increased survival of fry is expected if their downstream movement coincides in time with the period of maximum plankton abundance. In 1970, chum fry migrated downstream between April 20 and May 20, almost one month earlier than the previous year. This put them slightly ahead of the spring plankton peak which occurred in June of both years studied.

The timing of the chum migration in combination with a lowered overall plankton level for 1970 could have increased the early fry mortality rate. Survival values for Big Qualicum chum however were very close for both years: 0.63% for the 1968 brood year and 0.69% for the 1969 brood year. (Fraser, Bailey, Lightly & Perry, 1979). Early entrance to the Baynes Sound area may allow local fry to feed on the plankton before the influx of fry from other areas such as the Fraser River. A decrease in the survival rate of Fraser River chum was noted in 1970 (1969 brood stock) dropping from 2.02% in 1969 to 1.06% for 1970. These fish may have been partially affected by what appears to be an interaction between the timing of fry migrating downstream. If chum fry migrating down the Fraser river have at least a 27 day advantage over their Big Qualicum counterparts, their survival may be increased by as much as 0.5%. If the Fraser fry head downstream less than 27 days before the Big Qualicum fry, however, the survival advantage goes to the Qualicum fish. (D. Anderson and M. Bailey, Pink & Chum Workshop 1978). In 1970 earlier migration downstream of Big Qualicum fry meant only a 21 day lead for Fraser river fry.

CHUM FRY DIET

Examination of the stomach contents of over 1,600 chum and pink fry revealed that calanoid and harpacticoid copepods, euphausiid nauplii and *Oikopleura* made up over 75% of the diet, with *Oikopleura* remaining a major food item for both years.

A number of epibenthic items were identified among the stomach contents in 1970 (i.e. harpacticoids, mysids, cumaceans) While they were not expected to appear in the plankton samples, they do suggest that alternate food resources are exploited by pink and chum fry.

Parsons & LeBrasseur (1968) concluded that zooplankton biomass estimates alone do not give a realistic measure of food available to juvenile fry because the type of food influences its choice by fry. The chum fry examined from this study showed a degree of selectivity in their diet. For example although barnacle nauplii comprised about 30% of the mean plankton totals measured (and sometimes higher during their peak abundance), they made up less than 7% of the diet of smaller chum fry (April-June) and less than 2% of the diet of older chum juveniles. It is possible that such a small organism could be ingested accidentally. *Calanus plumchrus*, a large copepod (2-4 mm) was found in 80% of the fry stomachs examined during the first part of 1969. While the general abundance of this copepod decreased considerably in 1970, the fry continued to select it over the more abundant barnacle nauplii and copepodites.

PINK FRY

Pink salmon fry have been known to school very closely with chum fry (Feller, 1974) and intermixing of these two species was commonly observed in the Big Qualicum area during 1970. The results of this study indicate that the diet of pink and chum fry are similar, although pink fry may feed on a higher proportion of epibenthic organisms.

The position in the water column of pink fry migrating down the Fraser River is statistically shown (Appendix IX) as being deeper than that of chum fry (Mission Downstream data, Bailey & Fraser, 1979). Pink salmon may continue to occupy this lower niche, feeding in deeper water than do chum juveniles and therefore minimizing food competition between the two species.

Only a small sample of pink fry were examined during this study; therefore conclusive statements about their behaviour in relation to chum fry would require a more thorough investigation. It seems reasonable however that the possibility of competition for food and space between pink and chum salmon could exist in years of high production for both species.

FRY MORTALITY

The small size of salmon fry during their initial marine rearing period makes them very vulnerable to predation. Parker (1969) found that between 55% and 77% of the mortality of pink salmon fry occurred during the first 40 days of their marine life. The early downstream migration of Big Qualicum chum fry in 1970 could have put their brood year at a disadvantage because of their reduced size. The marine survival rates for chum salmon from the Big Qualicum system were similar with 0.63% survival observed for the 1968 brood year and 0.68% for the 1969 brood year.

The main predators of Big Qualicum chum fry were considered to be coho salmon and some 16 species of piscivorous

birds. Conditions which may also have a negative effect on fry survival are competition for food and space since fry from other areas also utilize these shallow coastal waters as temporary nursery grounds.

The idea that juvenile salmon stocks from surrounding locations converge upon specific geographic regions for rearing was proposed by Walters et al (1977) in the results of a workshop entitled "Potential Early Ocean Limitations of B.C. Salmon". This provides an explanation for the large number of non-resident pink and chum salmon observed in the Big Qualicum study area during 1970. If most chum migrate in a north-westerly direction as hypothesized earlier, then fry from Vancouver Island and lower mainland streams south of the Big Qualicum river might find the study area a suitable location to reside in before their final migration to the open sea. The implications of Baynes Sound as a "common rearing ground" should be considered with reference to the plans to increase chum fry production by adding spawning channels to Big and Little Qualicum Rivers and enhancing the Fraser River chum population. The production of more fry may cause increased crowding and competition for food and space among transient salmonid species utilizing this sheltered area.

PHYSICAL PARAMETERS

Conditions of water temperature and turbidity were largely the same during 1969 and 1970. Heavier rainfall probably accounts for the lowered salinity noted in 1969. Apart from the expected mid-summer rise in water temperature, no seasonal patterns were detected among the parameters measured.

Physical factors can affect plankton growth. Den Hartog (1960) has shown that conditions of high temperature and salinity disrupts the osmoregulation of phytoplankton and zooplankton, reducing their production potential. In the case of this study, insufficient data was collected to determine the effect that temperature and salinity had on zooplankton within the Big Qualicum study area.

Chum salmon have shown sensitivity to variations in salinity (MacInerney, 1964). Fry migrating seaward first choose areas of freshwater and gradually, during the summer, are drawn towards areas of increasing salinity. This is thought to be a possible orientation guide to their migration to the open ocean. As salinity measurements for this study were available from one station only, no correlation between fry movement and salinity can be made.

A physical factor which might influence plankton abundance is the amount of sunlight received each year in the study area. To test this idea, bimonthly totals for the number of hours of sunlight recorded at the closest meteorological station (Nanaimo) were plotted for each year (Figure 14). No direct correlation between hours of sunlight and plankton abundance was evident when graphs of the two were compared. In combination with other factors, however, sunlight encourages phytoplankton growth and indirectly may enhance the zooplankton

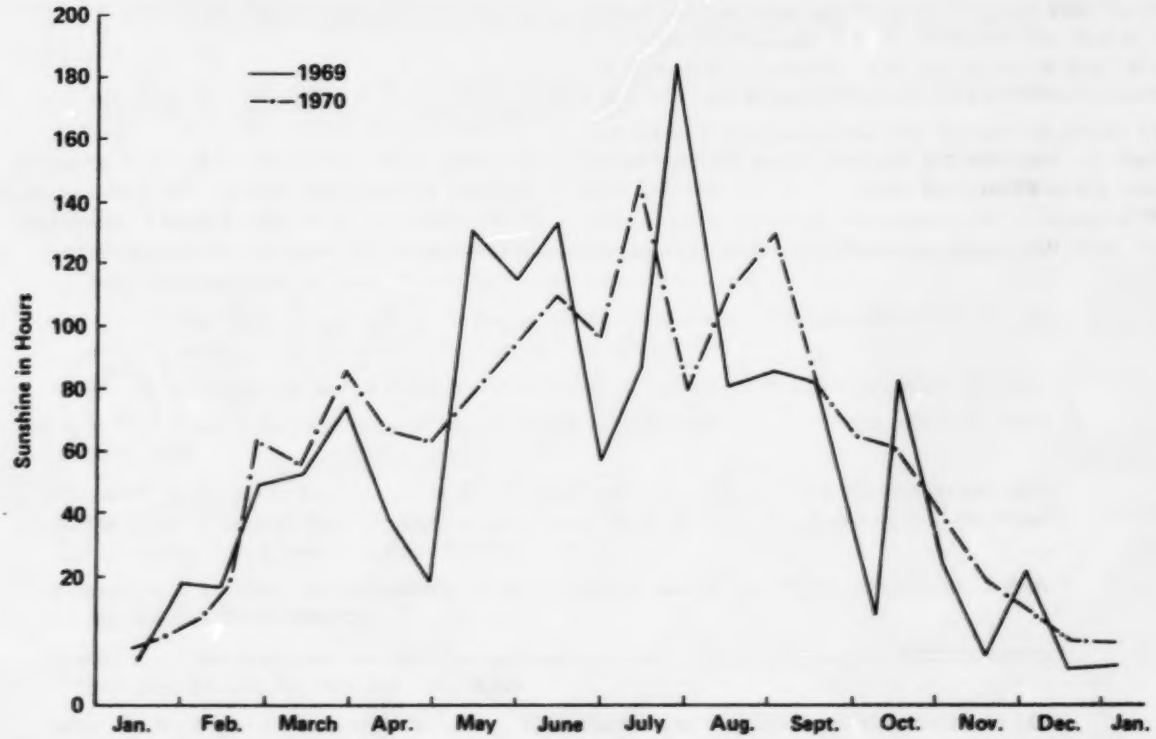


Figure 14. Daily sunshine totals for 1969 and 1970 for Nanaimo, B. C. (from the Monthly Records of Meterological Observations, Dept. of Transport, Meterological Branch).

population. It is expected that any increase or decrease in zooplankton abundance caused by sunlight would not appear immediately on a graph as a time lag is required between solar input and growth. In a computer analysis of eight physical and time variables measured during the study (ie. location - inshore or offshore, time of day, day, temperature, turbidity, salinity and total plankton measured), turbidity or secchi disc readings showed the highest correlation with plankton abundance. (Appendix VIII). The measurement of turbidity, however may actually represent an indirect measurement of the number of plankton present in the water column. Large numbers of plankton (a "bloom") will cause the water around them to appear cloudy or turbid, while their absence may result in clearer water. According to the correlation analysis 28% of the variation found in plankton abundance was accounted for by sunlight (Appendix VIII). This was a positive correlation, indicating that sunlight enhanced plankton growth. Using the values for total plankton obtained in this study along with two physical variables (sunlight and turbidity), a regression equation was calculated to predict the theoretical number of plankton present per m^3 (Appendix VIII). The results obtained were surprisingly close to those values estimated from actual sample counts. This suggests that given only the measurements of these physical parameters one may be able to crudely estimate the plankton levels for a specific location.

SUMMARY

A pilot study was undertaken during the late spring and summer of 1969 and 1970 to assess the migratory and feeding habits, growth and predation of Big Qualicum chum fry in particular, and chum fry of other streams in general. Major findings and recommendations are summarized below:

1. The results of marking and seining activities indicate that chum fry from the Big Qualicum River migrated northwesterly after entering salt water.
2. The migration of fry downstream should be timed to coincide with the period of maximum plankton abundance or "spring" peak. Increased mortality may result if large numbers of fry arrive during periods of low plankton abundance. The difference in timing for 1970 did not appear to affect Big Qualicum chum fry which entered the area early, but the survival rate of Fraser river chum fry, which arrived in the area later, was decreased.
3. It can be concluded that chum fry feed on a variety of organisms but show preference for certain species such as *Oikopleura* when present. Extreme fluctuations in the abundance of individual species probably discourages the dependence of fry on any one particular food type. Both the abundance and size of a plankton species affect its potential as prey.
4. Examinations of fry stomach contents revealed only slight diet differences between pink and chum salmon. In view of the relatively small number of pinks sampled, it is possible that more overlapping of diet does occur and competition for food may result in years of high chum and pink production.
5. A strong possibility exists that the waters surrounding Denman and Hornby Islands are utilized as a rearing ground by pink and chum salmon from other areas (see streams listed in Table 5). This area could be a strategic location for chum fry migrating northwards. The effects of further enhancing present chum fry production especially in the Big Qualicum and Fraser Rivers is not known specifically, but it could create crowding, competition and result in lower survival. It is recommended that a further study be made of plankton resources and the number of fry using the area.

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LITERATURE CITED

Bailey, J. E., B. L. Wing, and C. R. Mattson. 1975. Zooplankton abundance and feeding habits of pink and chum salmon. Fishery Bulletin 73(4): 846-860.

Bailey, M. D. and F. J. Fraser. 1979. Enumeration of salmonids in the Fraser river. Fish. Mar. Serv. Tech. Rep. (in preparation), Vancouver, B. C.

Brett, J. R. 1952. Temperature tolerance in young Pacific salmon. J. Fish. Res. Bd. Can. 9:265-323.

den Hartog C. 1960. Comments on the Venice system for the classification of brackish waters. Int. Revue ges. Hydrobiol. 45(4): 481-485.

Dunford, W. E. 1975. Space and food utilization by salmonids in marsh habitats of the Fraser river estuary. M. A. Sc. Thesis, Dept. of Zoology, University of British Columbia.

Feller, R. J. 1974. Trophic analysis of juvenile pink and chum salmon. Proceedings of the 1974 Northeast Pink and Chum Salmon Workshop, D. R. Harding (ed.) pp. 149-160.

Fraser, F. J., D. D. Bailey and M. D. Wood, 1978. Big Qualicum River Salmon Development Project (Vol. III), Experimental rearing of chum salmon juveniles (*Oncorhynchus keta*) in freshwater (1968-70) Fisheries and Marine Service. Technical Report number 752.

Fraser, F. J., D. T. Lightly, D. D. Bailey and E. A. Perry. 1979. Big Qualicum River Salmon Development Project (volume 1): Biological Assessment 1959-1972. Fish. Mar. Serv. Tech. Rep. (in preparation) Vancouver, B. C.

Freund, J. E. 1971. Mathematical Statistics, 2nd edition. Prentice-Hall Inc., New Jersey pp. 347-349.

Fry, H. D. 1961. Some problems in the marking of salmonids. Bull. Pac. Mar. Fish Comm. 5: 78-83.

Fulton, J. 1973. Some aspects of *Calanus plumchrus* J. Fish. Res. Bd. Canada 30: 811-815.

Goodman D. and Vroom, P. R. 1974. An assessment of the impact of proposed marina development on the fisheries resources of the Campbell River estuary. Fish. Mar. Serv. Tech. Rep. PAC/T-74-13.

Hardy, Sir A. 1970. The Open Sea: its Natural History, Part I. The World of Plankton. Great Britain, Chaucer Press.

Hart, A. C., M. B. Dell, and L. S. Smith. 1968. Tagging and sampling. International North Pacific Fisheries Commission Annual Report 1968, pp 68-79.

Healey, M. C., R. J. LeBrasseur, J. R. Sibert, W. E. Barraclough and J. C. Mason. 1976. Ecology of young salmon in Georgia Strait. Proceedings of 1976 Northeast Pacific Pink and Chum Salmon Workshop, G. K. Gunstrom (editor), pp. 201-207.

Heinrich, A. K. 1962. The life histories of plankton animals and seasonal cycles of plankton communities in the oceans. J. Cons. Perma. Int. Explor. Mer. 27(1):15-24.

Hourston, A. H. 1959. Locomotor performance of chum salmon fry *(Oncorhynchus keta)* during osmoregulatory adaptation to sea water. Can. J. Zool. 37: 591-605.

Hunter, J.G. 1959. Survival and production of pink and chum fry. J. Fish. Res. Bd. Can. 16(6): 835-886.

Ito, J. 1964. Food & feeding habits of Pacific salmon in their ocean life. J. Fish. Res. Bd. Can. Transl. series 1309.

LeBrasseur, R. J., W. E. Barraclough, O. D. Kennedy and T. R. Parsons. 1969. Production studies in the Strait of Georgia Part III: Observations on the food of larval and juvenile fish in the Fraser river plume. J. Exp. Mar. Biol. Ecol. 3: 51-61.

MacInerney, J. E. 1964. Salinity preference: an orientation mechanism in salmon migration. J. Fish. Res. Bd. Can. 21(5): 995-1018.

Manzer, J. I. 1969. Food and feeding of juvenile Pacific salmon in Chatham Sound and adjacent waters. Fish. Res. Bd. Can. Ms. Rep. Ser. 120, 18 pps.

Parker, R. R., Black, E. C., and P. A. Larkin. 1961. Some aspects of fish-marking mortality. In I.C.-N.A.F.N. Atlant. Fish. Mark. Symp. Spec. Publ. (4): 117-122, 1963.

Parker, R. R. 1968. Mortality of juvenile pink salmon in central B. C. coastal waters. Fish. Res. Bd. Can. MS Report series 956, 5 pp.

Parker, R. R. 1969. Predator-prey relationship among pink and chum salmon fry and coho smolts in a central British Columbia inlet. Fish. Res. Bd. Can. MS Rep. Ser. 1019, 7 pp.

Parker, R. R. 1971. Size selective predation among juvenile fishes in a British Columbia inlet. J. Fish. Res. Bd. Canada 28: 1503-1510.

Parsons, T. R. and R. J. LeBrasseur, 1968. The availability of food to different trophic levels in the marine food chain. In J. H. Steel (ed.) Marine Food Chains, Oliver and Boyd, Edinburgh, 1970.

Parsons, T. R., K. Stephens and R. J. LeBrasseur. 1967. Production studies in the Strait of Georgia Part I. Primary production under the Fraser river plume, February to May, 1967. J. Exp. Mar. Biol. Ecol. 3: 27-38.

Parsons, T. R. and M. Takahashi. 1973. Biological Oceanographic Processes. Toronto, Pergamon Press, p. 17.

Rousenfell, G. A. and H. W. Everhart. 1953. Growth in Fishery Science, its methods and applications. John Wiley and Sons, New York pp. 311-315.

Ruttner, F. 1972. Fundamentals of Limnology, Unv. of Toronto Press, Toronto, 295 pp.

Semko, R. S. 1954. A method of determining the consumption by predators of the young Pacific salmon during the early stages of development. Trudy Sov. metizuch kormovoi basy i pit. ryb. 6 pp. 124-134 Trans. from Russian by R. E. Foerster, 1959 (Fish. Res. Bd. Can. Transl. Ser 215).

Vanstone, W. E., J. R. Markert, D. B. Lester and M. A. Giles. 1970. Growth and chemical composition of chum *(O. keta)* and sockeye *(O. nerka)* salmon fry produced in spawning channel and natural environments. J. Fish. Res. Bd. Can. 27(2): 371-382.

Walters, C. J., R. Hillborn, R. M. Peterman, M. J. Staley. 1977. Potential Early Ocean Limitation of B. C. Salmon Production, Workshop Progress Report PR-7, Institute of Resource Ecology, University of British Columbia, Vancouver, B. C.

Zyblut, E. R. 1972. The 1972 report on chum salmon stocks of the Johnstone Strait-Fraser river study area. Envir. Can. Fish. Ser. Tech. Rep. 1972-9 11 pp.

APPENDICES

Appendix I. Big Qualicum River chum fry downstream ($x10^6$).

Brood Year	Main River Above Fence	Main River Below Fence	Total Main River	Spawning Channel Number 1	Spawning Channel Number 2	Freshwater Rearing	Total System
1960	3.6	1.0	4.6	–	–	–	4.6
1961	3.4	1.1	4.5	–	–	–	4.6
1962	5.1	1.8	6.9	–	–	–	6.9
1963	15.0	4.1	19.1	1.8	–	–	20.9
1964	10.8	4.5	15.3	0.1	–	–	15.4
1965	7.1	2.5	9.6	0.7	–	–	10.3
1966	17.6	3.1	20.7	1.1	–	–	21.8
1967	12.9	8.7	21.6	0.6	11.6	0.2	33.9
1968	28.1	6.2	34.3	–	15.3	2.1	51.7
1969	32.0	10.0	42.0	–	19.5	1.6	63.1
1970	20.9	6.8	27.7	–	20.4	–	48.1
1971	14.0	5.2	19.2	–	17.5	–	36.7
1972	12.9	9.0	–	–	21.7	–	43.6

(Fisheries unpublished data)

Appendix II. Estimated chum salmon fry production for the Big Qualicum area, 1969 and 1970.

	Big Qualicum System Brood Year		11 Other Local Rivers [e] Brood Year	
	1968	1969	1968	1969
No. spawners	140,384	101,016	184,350	118,650
No. females [a]	71,801	52,326	94,203	61,461
Egg deposition [b]	239,840,000	172,047,890	314,167,005	202,083,770
Fry downstream	51,700,000 [c]	63,100,000 [c]	47,125,050 [d]	30,312,570 [d]

[a] Based on Big Qualicum spawning ground data of 51.1 and 51.8 percent of females for 1968 and 1969 respectively.

[b] Based on Big Qualicum fecundities for chum salmon of 3,335 and 3,288 eggs/ female for 1968 and 1969.

[c] Actual fry production.

[d] Potential fry production, assuming 15% egg to fry survival.

[e] Refer to Table 2.

Appendix III. Fry-to-adult survival rates of chum fry from the Big Qualicum River.

Brood Year	Total Fry ($x10^6$) Downstream	Total Adult Return	Fry-to-adult Percent Survival
1959	21.1	98,000	.46
1960	4.5	48,000	1.05
1961	4.5	19,000	.42
1962	6.8	44,000	.64
1963	20.9	55,000	.26
1964	15.4	152,000	.98
1965	10.3	146,000	1.42
1966	21.8	312,000	1.43
1967	33.9	111,000	.33
1968	51.7	322,000	.62
1969	63.1	433,000	.69
1970	48.1	35,200	.07
1971	36.7	125,000	.34*
1972	43.6	213,000	.48*

* Preliminary estimate

Appendix IV. Mean Plankton Densities (No./m^3) for Major Species (Inshore stations, 1970).

Sampling Date	Calanoid Copepod	Calanus plumchrus	Harpacticoid	Barnacle Nauplii	Evadne	Oikopleura	Polychaete	Oithona
April 20	1,207	123	7	2,075	77	282	171	1,710
May 1	425	15	25	2,492	21	263	177	1,310
May 5	740	1	10	5,029	189	556	47	616
May 11	1,819	5	4	5,721	855	1,314	318	654
May 20	1,143	–	9	2,996	1,617	1,922	76	788
May 30	2,224	–	289	2,015	1,854	1,726	365	2,111
June 12	3,674	5	10	3,710	2,121	1,875	70	1,809
June 23	2,486	–	22	6,464	1,142	1,081	225	1,434
July 13	1,508	2	17	146	692	293	10	325
July 27	2,443	–	30	1,080	2,213	1,176	196	4,718
August 7	2,790	14	110	2,230	663	1,289	74	5,943
August 17	2,229	–	234	2,396	1,308	1,354	195	2,917
August 28	506	–	196	4,053	1,853	1,539	330	6,834
September 8	1,400	–	51	8,123	1,566	2,438	559	6,035

Appendix V. Potential marine avian predators of salmonid fry in the Big Qualicum study area, 1969 - 1970.

Family	Common Name	Genus and Species
Cormorants	Pelagic Cormorant	*Phalacrocorax urile*
	Double-crested Cormorant	*Phalacrocorax auritus*
Grebes	Western Grebe	*Aechmophorus occidentalis*
	Horned Grebe	*Podiceps auritus*
	Red-necked Grebe	*Podiceps grisegena*
Guillemots	Pigeon Guillemot	*Cepphus columba*
Gulls	Glaucous-winged Gull	*Larus glaucescens*
	Herring Gull	*Larus argentatus*
	Bonaparte's Gull	*Larus philadelphis*
Herons	Great Blue Heron	*Ardea herodias*
Loons	Common Loon	*Gavia immer*
	Arctic Loon	*Gavia arctica*
Mergansers	Common Merganser	*Mergus merganser*
Murrelets	Marbled Murrelet	*Brachyramphus marmoratum*
Murres	Common Murre	*Uria aalge*
Terns	Common Tern	*Sterna hirundo*

Appendix VI. 1969 Secchi disc readings (m) in the Big Qualicum marine study area (on = onshore station; off = offshore station).

Date	Qualicum Bay		Deep Bay		Mud Bay		Fanny Bay		Buckley Bay		Comox Harbour		Tribune Bay		Boyle Point		Bowser	
	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off
April 12	6.9	10.2	9.0	9.0	6.0	6.3	7.5	7.2	7.2	6.3	–	–	11.1	17.4	12.6	15.6	9.0[a]	12.2
April 22	6.6	7.5	6.6	6.0	4.5	4.5	6.0	4.5	8.4	4.5	–	–	9.6[a]	6.6	6.0	7.5	7.5	7.5
May 1	6.9	6.0	5.4	6.0	5.7[a]	5.1	5.1	6.3	5.1	6.0	–	–	7.5	7.5	6.9	7.2	6.9	6.9
May 12	2.4	2.4	2.1	2.1	2.4[a]	2.4	2.4	2.4	2.4	2.4	2.4	2.4	3.0	3.0	2.4	2.4	2.4	2.1
May 22	7.2[a]	6.5	–	–	–	–	–	–	–	–	–	–	6.0[a]	6.5	3.0	3.0	3.8[a]	3.8
May 23	–	–	3.6	3.3	3.8	3.8	3.8	3.6	3.9	3.8	3.6	3.6	–	–	–	–	–	–
June 3	6.0	5.7	2.7	2.4	3.0	3.0	4.5	4.2	4.2	4.5	4.5	4.5	6.0	5.4	4.2	4.2	6.0	5.4
June 18	5.4	6.9	3.9	3.9	3.9	4.5	4.8	5.4	4.8	6.0	3.9	4.8	6.3	6.9	4.8	5.4	6.0	5.4
June 27	4.8	4.8	3.6	4.5	4.5	4.2	3.6	3.9	4.2	4.2	4.5	5.7	5.1	5.4	5.1	5.1	4.8	4.8
July 8	7.2	7.2	5.4	5.4	6.0	5.4	5.7	6.0	5.7	5.7	5.7	5.4	6.9	6.6	5.7	6.3	5.7	5.7
July 18	6.3	6.9	5.1	5.1	5.0	5.7	5.4	4.8	5.7	5.7	6.0	5.7	6.2	6.2	6.0	5.9	6.3	6.9
July 29	4.0	3.9	3.3	3.5	4.1	3.8	4.1	3.9	3.9	3.9	4.2	4.8	4.8	4.8	3.8	3.9	4.1	4.1
Aug. 7	4.2	4.5	4.4	4.2	4.5	4.7	4.8	4.7	5.0	5.0	4.5	4.7	4.5	4.7	4.4	5.0	4.8	5.0
Aug. 18	4.8	4.5	–	–	–	–	–	–	–	–	–	–	6.6	6.6	–	–	–	–
Aug. 19	–	–	7.5	6.0	7.5	7.2	6.6	6.6	6.6	6.3	4.5	4.8	–	–	6.3	5.7	6.6	7.2
Sept. 4	5.1	3.9	5.7	4.8	6.0	5.7	5.7	5.7	6.0	5.1	5.4	4.8	5.1	4.8	6.0	6.3	5.4	5.4

[a] Secchi disc on bottom.

Appendix VII. 1970 Secchi disc readings (m) in the Big Qualicum marine study area (on = onshore station; off = offshore station).

Date	Qualicum Bay		Deep Bay		Mud Bay		Fanny Bay		Buckley Bay		Comox Harbour		Tribune Bay		Boyle Point	
	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off
April 20	–	–	1.5	1.5	4.2	1.8	2.7	2.4	2.7	2.4	2.1	2.4	4.5	9.0	3.0	10.5
May 1	4.8	–	–	–	–	–	–	–	–	–	–	–	4.2	3.9	–	5.7
May 4	–	–	–	–	–	–	–	–	4.5	–	3.0	4.5	–	–	–	–
May 5	–	–	4.8	3.3	4.2	3.0	4.5	3.0	–	3.0	–	–	–	–	9.0	–
May 11	6.3	5.7	5.4	3.0	3.6	3.0	4.2	3.6	4.5	3.3	4.8	5.1	3.0	3.0	5.1	3.6
May 20	3.6	3.0	4.5	3.0	–	–	–	–	–	–	–	–	3.0	3.0	2.7	2.7
May 21	–	–	–	–	–	–	–	–	–	–	4.5	4.5	–	–	–	–
May 30	3.6	6.9	3.6	3.9	3.0	3.9	3.6	3.3	3.3	3.0	4.8	5.4	5.1	5.1	4.5	3.3
June 11	3.0	3.6	–	–	–	–	–	–	–	–	3.6	4.8	4.5	–	–	–
June 12	–	–	4.5	4.5	4.5	4.2	4.2	4.5	3.6	4.2	–	–	–	5.1	4.5	4.2
June 23	6.9	9.9	5.1	5.7	5.4	5.4	6.3	5.1	4.5	6.3	4.5	4.5	6.0	9.0	5.7	6.6
July 13	6.0	9.3	–	–	–	–	–	–	–	–	3.0	3.0	6.0	9.6	4.5	8.1
July 14	–	–	5.7	6.3	5.7	6.9	5.1	10.5	3.9	6.9	–	–	–	–	–	–
July 27	4.5	6.3	4.8	4.5	–	–	4.5	–	4.2	3.9	4.5	3.0	4.2	8.4	3.0	11.1
August 7	6.0	5.4	4.2	4.2	3.3	4.2	3.9	4.8	4.5	4.2	3.9	3.6	4.5	5.4	4.5	4.8
August 17	4.2	7.8	–	–	3.0	4.2	4.8	5.1	4.2	4.5	4.5	4.5	5.7	8.4	7.2	8.4
August 28	5.1	5.7	3.9	3.3	3.9	3.9	3.9	4.8	3.3	4.2	5.1	4.8	3.0	6.6	4.2	5.7
Sept. 8	4.2	4.5	3.9	3.3	4.5	3.6	4.8	3.9	3.9	3.9	5.4	5.7	3.0[a]	4.5	3.3[a]	6.0

[a] Secchi disc on bottom.

Appendix VIII. Correlation Matrix of Physical Factors with 1970 Inshore Plankton Abundance for Big Qualicum Area.

Variable	Plankton	Temperature	Salinity	Secchi	Sunlight
Number of Plankton	1,000	0.1618	-0.1298	-0.6801	0.5351
Temperature		1.000	0.1531	0.3584	0.8000
Salinity			1.000	0.067	0.4138
Secchi				1.000	- 0.048
Sunlight					1.000

Regression Analysis for 1970 Inshore Plankton Abundance.

Regression Equation: $Y = -794.753$ (Secchi Disc Reading) + 54.201 (Sunlight) + 21115.675

$F = 6.271$

$F_{.05, 5} = 5.79$

Sampling Date	Actual Plankton Counts (No. /m^3)	Computed from Regression equation (No./m^3)
May 4	8,750	10,950
May 11	14,986	12,937
May 30	15,790	17,987
June 11	16,402	15,209
June 23	14,254	11,721
July 13	8,794	8,861
August 7	17,594	15,657
August 28	16,680	17,973

Appendix IX. Nonparametric U-Test.

Hypothesis: Pink and chum fry occupy the same depth in the water column.
Based on: Mission Downstream data for 1968 (see Bailey and Fraser, 1975).

$$u = n_1 n_2 + n_1 \frac{n_1 + 1)}{2} \cdot R_1$$

$$u = (45)(45) + 45 \frac{(45 + 1)}{2} \cdot 1092.5$$

$$u = 1967.5$$

$$E(u) = \frac{n_1 n_2}{2} = 1012.5$$

$$Z = \frac{u \cdot E(u)}{Var(u)} = 7.7$$

$$Var\ (u) = \frac{n_1 n_2\ (n_1 + n_2 + 1)}{12} = 1536.2$$

$$Z_{.95} = 1.96$$

where n_1 = sample size of chum
n_2 = sample size of pinks
R_1 = sum of the ranks assigned to the values of n_1

Therefore $n_1 = n_2$ or there is a significant difference between the number of pinks and chum which inhabit depths up to 3.6 meters. Pink fry in the Fraser river are found in deeper water than chum fry.

The disparity or difference between the two groups was great enough that only one year's data was tested. A look at the numbers from other years supports this pattern.

Appendix X. Chum fry stomach contents, 1969.

Organism	June 14 - June 25					
	n = 22 Fry 50 mm		n = 148 Fry 50 - 70 mm		n = 16 Fry 70-100 mm	
	Number Found	Number Stomachs	Number Found	Number Stomachs	Number Found	Number Stomachs
Barnacle nauplii	1	1	20	33	–	–
Calanus plumchrus	169	16	3,032	129	723	16
C. plumchrus nauplii	–	–	18	5	–	–
Centrophages	–	–	48	9	–	–
Copepod nauplii	83	6	390	23	3	2
Crab zoea	–	–	–	–	1	1
Euphauiid nauplii	253	2	30	8	–	–
Evadne	30	4	178	27	1	1
Fish larva	1	1	6	5	–	–
Gastropoda	–	–	5	5	–	–
Insecta	6	3	27	20	3	3
Oikopleura	4,225	20	43,422	140	7,913	14
Parathermista	2	2	3	3	–	–
Podon	582	4	3	2	–	–

Organism	July 1 - August 1			
	n = 53 Fry 70-100 mm		n = 38 Fry 100 + mm	
	Number Found	Number Stomachs	Number Found	Number Stomachs
Barnacle nauplii	–	–	8	2
Calanus plumchrus	–	–	2	2
C. plumchrus copepodites	70	1	1	1
Calanus pacificus	1,345	53	561	21
C. pacificus copepodites	5,185	51	1,315	19
Crab zoea	16	6	51	10
Euphausiid nauplii	2,525	52	2,486	24
Fish larva	8	3	2	1
Gastropoda	–	–	3	1
Insecta	12	5	1	1
Parathermista	11	6	8	5
Oikopleura	631	11	1,105	7

Appendix XI. Chum fry stomach contents, 1970.

April - June

Organism	n = 509 Fry 50 mm		n = 172 Fry 50-70 mm		n = 229 Fry 70 + mm	
	Number Found	Number Stomachs	Number Found	Number Stomachs	Number Found	Number Stomachs
Amphipod	216	67	233	29	172	26
Barnacle cypris	465	113	750	75	100	16
Barnacle nauplii	191	39	93	18	33	5
Calanoid copepodite	721	99	14	7	89	9
Calanus plumchrus	406	75	218	26	781	52
Calanus pacificus	219	37	–	–	–	–
Copepod nauplii	193	17	206	14	–	–
Centrophages	21	6	57	9	68	9
Crab zoea	4	3	25	12	41	14
Decapod larva	550	74	33	4	–	–
Euphausiid nauplii	4,596	134	7,215	123	3,189	94
Evadne	3,034	124	2,816	55	261	7
Harpacticoid copepod	1,341	209	106	16	22	8
Insecta	252	43	135	37	17	12
Mysid	163	25	1,186	38	832	54
Oikopleura	2,579	85	8,004	107	28,783	122
Podon	2,924	49	76	8	9	4
Polychaeta	3,031	181	734	40	19	9
Pseudocalanus	14	10	14	7	44	15
Sagitta	–	–	–	–	426	12

July - September

Organism	n = 221 Fry 70 + mm	
	Number Found	Number Stomachs
Amphipod	82	17
Adult crab	218	7
Barnacle cypris	3	3
Calanoid copepodite	45	12
Calanus plumchrus	40	13
Crab zoea	537	30
Decapod larva	8	3
Euphausiid nauplii	143	55
Evadne sp.	43	2
Fish larva	132	14
Insecta	20	7
Mysids	45	10
Oikopleura	4,807	70
Oithona	2	2
Other	211	2
Polychaeta	41	13
Pseudocalanus	8	6

Appendix XII. Pink fry stomach contents, 1970.

Organism	April - June					
	n = 43 Fry 50 mm		n = 94 Fry 50-70 mm		n = 80 Fry 70 + mm	
	Number Found	Number Stomachs	Number Found	Number Stomachs	Number Found	Number Stomachs
Amphipod	14	6	246	18	125	18
Barnacle cypris	13	8	288	32	15	6
Barnacle nauplii	11	3	2	2	–	–
Calanoid copepodite	49	5	46	15	25	9
Calanus plumchrus	13	7	137	6	335	18
Centrophages	5	2	265	3	6	4
Copepod nauplii	111	12	6	15	16	1
Crab zoea	–	–	5	–	10	2
Decapod larva	6	4	2	2	1	1
Euphausiid nauplii	148	10	493	36	1,872	35
Evadne	243	13	474	14	31	2
Fish larvae	–	–	–	–	4	2
Harpacticoid copepods	723	32	2,880	64	1,902	54
Insecta	2	2	17	12	6	6
Mysids	5	2	25	13	342	19
Oikopleura	121	10	1,302	51	2,949	38
Oithona	1	1	6	5	9	5
Others	–	–	46	1	1	1
Polychaeta	48	9	37	6	9	2
Podon	90	3	7	5	–	–
Pseudocalanus	5	3	13	7	10	5
Tortanus discaud	4	2	5	4	6	4

Organism	July - September, 1970	
	n = 29 Fry 70 + mm	
	Number Found	Number Stomachs
Amphipod	1	1
Calanoid copepodite	2	1
Calanus plumchrus	8	3
Crab zoea	227	9
Euphausiid nauplii	117	11
Fish larvae	17	4
Harpacticoid copepods	9	4
Mysids	1	1
Oikopleura	325	6
Oithona	1	1
Others	1	1
Polychaeta	42	10